STRATEGY RESEARCH PROJECT

A STRATEGIC ANALYSIS OF COMMERCIAL SATELLITE COMMUNICATIONS ENTERPRISES AND THEIR ROLE FOR THE WARFIGHTER OF THE FUTURE

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A Strategic Analysis of Commercial Satellite Communications Enterprises and their Role for the Warfighter of the Future

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ABSTRACT

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Satellite communications capabilities is today, and will be in the future, the critical enabler in achieving information dominance needed for Joint Vision 2010. This paper will discuss why this is so by baselining the current communications requirements as well as the emerging requirements of JV2010 and comparing the currently programmed capabilities in the military satellite communications architecture as defined by the DOD Space Architect and Deputy Under Secretary of Defense for Space.

After initially setting the baseline, the paper will discuss the ability of the exploding commercial satellite communications market to meet some, if not most of the uniquely military requirements (the pros) as well as the difficulties raised and/or military risk assumed (the cons) in exploiting the commercial offerings. In doing so a dozen or so serious commercial ventures

are discussed. The paper also addresses how the DOD should leverage from the commercial systems.

The following commercial enterprises are discussed: Transponded and trunked service - Intelsat and the like; Mobile Services - Iridium, Globalstar, Odyssey, ICO; Switched Bandwidth Systems - Spaceway, Astrolink, Cyberstar, Celestri, Teledesic.

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INTRODUCTION

> "Improvements in information and systems integration technologies will also significantly impact future military operations by providing decision makers with accurate information in a timely manner. Information technology will improve the ability to see, prioritize, assign and assess information…Forces harnessing the capabilities potentially available from this system of systems will gain dominant battlespace awareness" [1]

The current National Military Strategy (NMS) calls for a Revolution in Military Affairs (RMA) both organizationally and doctrinally and focuses on technological innovation and information superiority as the ways to maintain military superiority.[2] In fact the Chairman's Joint Vision 2010 key enablers of information superiority and technical innovation will transform the current concepts of maneuver, strike, protection and logistics into the new operational concepts of dominant maneuver, precision engagement, full-dimensional protection and focused logistics.[3] In order to maintain military preeminence with less force structure, we must leverage information technology to increase war-fighter capability.

Both the NMS and Joint Vision 2010 cite Information Warfare (IW) as the means for achieving information superiority primarily on the basis of moving bit streams to and around the battlefield, while disrupting the enemies ability to do the same. Clearly the success of the Gulf War can be largely attributed to our

technological advantage in stealth, precision munitions which devastated the Iraqi sensors and command and control communications networks while maintaining our information sources and transmission means intact. One could argue that the "system of systems" was in its infancy during the Gulf War. The problem facing the military is finding a cost effective way to achieve information superiority, in balance with the required improvement of other warfighter systems, be they weapons platforms, munitions, sensor systems or the logistic support needed to maintain them on the battlefield. The Quadrennial Defense Review outlines the steps necessary for the DOD to take, in order to pay for these improvements. The military must sacrifice some force structure and do away with some unneeded infrastructure while maintaining a fairly stable budget that allows for adequate investment in R&D and force modernization. Given the drawdown in force structure since the Gulf War and the political pressure to shrink the military further, our ability to achieve the vision is tightly hinged on our ability to achieve information superiority. That superiority in large is achieved by the communications connectivity between the mobile widely dispersed joint forces and weapons platforms, and the command, intelligence and logistics centers. The inherent capabilities of satellite communications (SATCOM) include instant accessibility, survivability, coverage,

flexibility and global reach. These inherent capabilities make satellite communications the only realistic means of providing much of the connectivity necessary to achieve the system of systems.[4]

Today the armed forces primarily look to the military satellite communications (MILSATCOM) architecture, which was designed in the 70's and 80's, to satisfy these needs, with some dependence on commercial satellite offerings. This can be attributed to the fact that the Defense Department was driving the technology in the cold war era. The growing information revolution today has changed the paradigm in all communications media, to include the commercial satellite industry. This paper will explore the current and projected MILSATCOM architecture, the exploding MILSATCOM requirements as well as the emerging commercial endeavors, and how the DOD can best exploit the technology driven by commercial industry to satisfy these requirements in the most cost-effective way.

MILITARY SATELLITE COMMUNICATIONS

The primary requirements that drove the design of military satellite systems in the 70's were the nuclear command and control systems. To understand the systems, one must consider the entire system, that being the space segment as well as the

ground and control segments. During the early cold war era, the U.S. ability to provide early warning from sensors, process that data in order to make response recommendations to the National Command Authorities (NCA), and to promulgate those decisions to the nuclear triad forces was severely lacking. The Defense Support Program satellite system was developed to enhance our ability to detect ballistic missile launches and provided redundant sensing capability to our ground based radars. Nuclear war scenarios of the time identified shortfalls in passing the warning data as well as force direction in a nuclear perturbed and jammed environment. The AFSATCOM, Fleet SATCOM (FLTSATCOM) and Defense Satellite Communications System (DSCS) programs were designed to work through some of that dirty environment.

The FLTSATCOM and AFSATCOM systems both work primarily in the Military UHF Spectrum (300 MHz). Each FLTSATCOM satellite provides twenty-three channels. The Navy uses ten channels of FLTSATCOM; one SHF anti-jam uplink to UHF one-way downlink broadcast to the fleet and nine, 25 kHz UHF channels for Navy general purpose two way communications. Twelve, 5 kHz channels and one, 500 kHz channel of the satellite are used for nuclear force direction. This portion of the satellite is also known as the AFSATCOM package. Seven of the 5 kHz channels are regenerative, meaning the signal is received by the satellite,

processed and cleaned up and transmitted back to earth. The other 5 kHz channels are not regenerative (transmits what is received by the satellite). The 500 kHz channel is a shared transponder usually divided into twenty-one sub-channels for 25 kHz general purpose access, as well as JCS/CINC frequency hopped internet circuits. The primary advantage of these UHF systems is their small size and simplicity of the terminals, which are used by all Services in the air, on the ground, and at sea. The satellite constellation at this frequency provides for worldwide coverage between 75 degrees north and south latitude. The other uniquely military capability that is exploited in these systems is netted communications (that being the ability to essentially conference many users simultaneously on one channel or net). In order to provide 24-hour coverage in the North Polar Region, the AFSATCOM package is also hosted on satellites in polar orbit. These packages are essential for communications to nuclear bomber forces operating over the pole in the execution of the Single Integrated Operation Plan (SIOP).[5]

The DSCS program was designed to meet both strategic and tactical communications requirements from the White House down to the foxhole. It provides approximately 400 MHz of communications bandwidth in the SHF frequency band (7.25 - 8.4 GHz). The

current constellation calls for five fully capable primary satellites with a residual capability (currently five partially capable older satellites). Each DSCS III satellite has six independent channels connected to an assortment of antennas that are shared by a wide mix of users. Each current DSCS satellite has two 40-watt channels (1 and 2) and four 10-watt channels (3-6). The low power channels provide the means for high bandwidth communications pipes between strategic earth terminals with 40 to 60 foot antennas. The DSCS has the ability to locate a jammer and reconfigure its multi-beam receive antenna to null out the jammer providing the essential means to communicate in the hostile nuclear environment. Channel 1 was designed to operate the Jam-Resistant Secure Communications (JRSC) network, which provided the survivable communications between the NAOC (National Airborne Operations Center for the NCA) mobile command centers and ballistic missile sensor sites. Channel 1 also is shared by an AFSATCOM package called the Single Channel Transponder (SCT). This channel is configured to run strictly high power, low bandwidth spread spectrum ("stressed") users which preclude normal users from sharing the channel. Channel 2, the other high power transponder, was originally designed to support the ground based tactical multi-channel requirements (8 and 20 foot antennas) with the high gain spot antenna.

The DSCS-III has been the workhorse for the DOD since the early eighties satisfying the critical nuclear, command and control, intelligence, and Defense Information System Network (DISN) backbone requirements worldwide. To do that however, it can not be optimally configured for any particular user as the satellite antennas and channels are shared. In light of the fact that the cold war is over, the Joint Staff has put a high priority in shedding some strategic DSCS users, to provide more tactical capability. Channel 1 in three of the five primary satellites has been "de-stressed" to provide more tactical capacity. In January 1996, DOD approved enhancing the four remaining to be launched DSCS III satellites by upgrading them with six 50 Watt channels in the DSCS Service Life Enhancement Program (SLEP). This additional power will facilitate moving the strategic users from channels 1-4 into channels 5 and 6, providing the warfighter three times the worldwide tactical capacity available today.

Because of the poor UHF system performance in a jammed and nuclear scintillated environment (that produced by a nuclear event in the atmosphere causing ionization and other effects degrading communications) and since the DSCS III system was deemed to be not as robust as required, a new more survivable and robust Milstar system was developed. It uses a much higher

frequency spectrum at SHF and EHF. The wider bandwidth available, the tighter signal beams inherent at those frequencies, and the satellite processing of the waveform allows for better anti-jam (AJ) performance and anti-scintillation (AS) in a nuclear perturbed environment than the DSCS system. The Milstar program has two Milstar satellites in orbit today with four in different stages of development. The final operational capability (FOC) requires four satellites in geosynchronous positions to provide worldwide coverage between the 75 degrees north and south latitudes. The first two satellites were configured with only a low data rate (LDR) package in support of nuclear command and control. The final four will be configured with a high data rate (HDR) capability (approximately 40 MBps of AJ capacity to tactical users) as well as the LDR capability. It is envisioned that all AFSATCOM and DSCS JRSC users will migrate to Milstar early in the next century. The Fleet Broadcast users will also migrate to the EHF spectrum on the Milstar compatible FLTSATCOM EHF package (FEP), which was launched on FLTSATCOM 7 and 8 as well as all the UHF Follow-on (UFO-E) systems, which replace the FLTSATCOM constellation. As the FEP does not process the signal as Milstar does, it is not as robust for AJ/AS communications as Milstar.[6]

One of the biggest problems cited during the Gulf War was our ability to get relevant and timely intelligence products to the theater for Battle Damage Assessment (BDA). To rectify this shortfall, DOD kicked off the formal program called Global Broadcast System (GBS) in 1995 as well as an Advance Concept Technology Demonstration (ACTD) called JBS (Joint Broadcast System) for support to Bosnia operations. The primary reason for GBS program existence is to provide the high bandwidth one way feeds from both national systems as well as in-theater Unmanned Airborne Vehicle (UAV) sensor systems to multiple echelons of forces in-theater having small "DirecTV-like" terminals. The ACTD was intended to exploit the available commercial direct broadcast capability and develop both the procedures and operational concepts for the GBS. In phase 2 of the program, a GBS package operating in the military Ka-band will be hosted on the next three UFO-E launches to provide worldwide GBS coverage.

The control segment of all of MILSATCOM systems in the architecture is operated and maintained by the Air Force, Navy and the Army. The Air Force essentially flies all the military payloads less the UHF systems (FLTSATCOM and UFO-E) which are flown by the Navy. The communications platforms are managed and controlled by the three Services under JCS direction (DSCS-Army/DISA, UFO/FLTSATCOM - Navy, and the rest Air Force). The

necessary overhead cost in the control segment is sometimes overlooked as they are primarily funded by O&M vice program dollars.

The Requirements Capability Mismatch in MILSATCOM

The currently deployed MILSATCOM architecture consists of the different satellite constellations and their respective capacity measures as displayed in Figure 1. All of the current

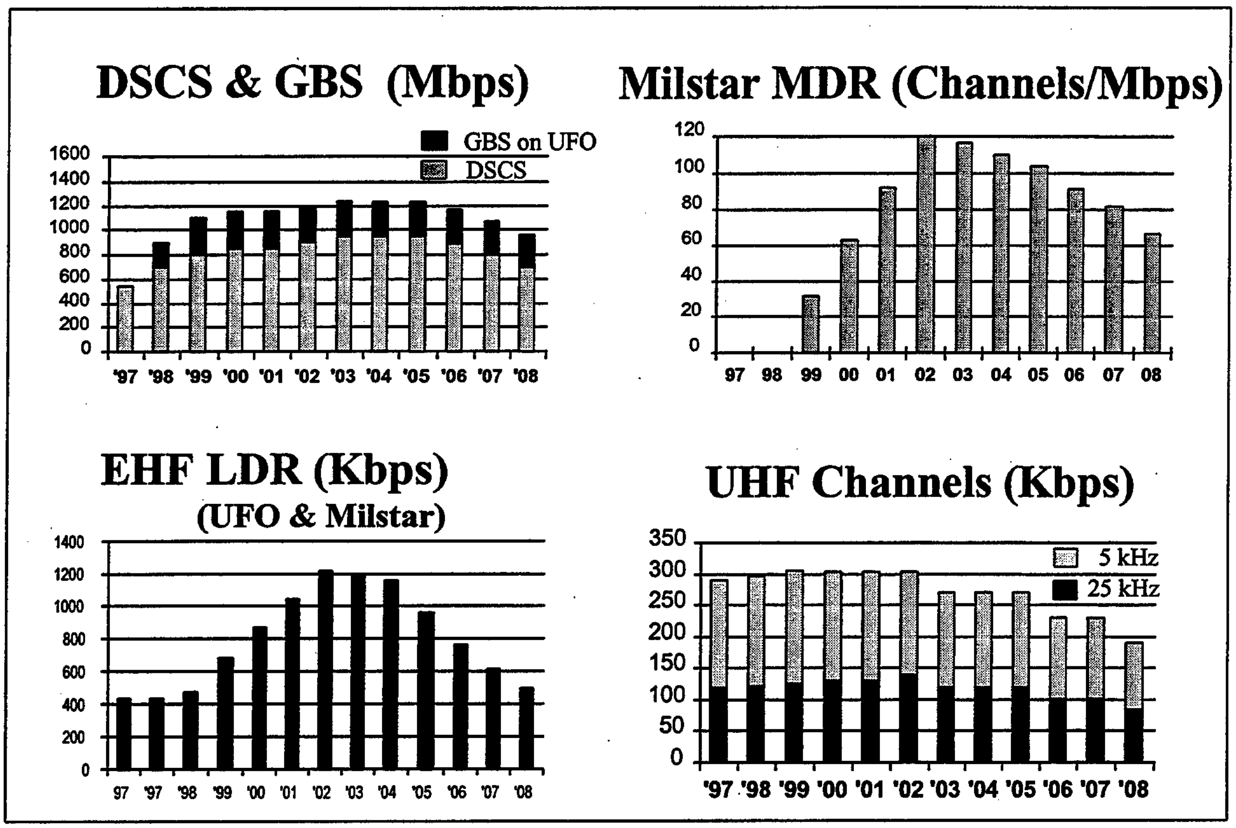

Figure 1. Predicted Available Legacy Capacity (DOD-Owned)[7]

systems are predicted to begin degradation of their designed capability between 2003 and 2005. It should be noted that their designed capabilities were identified to satisfy requirements

envisioned in the 1980's, not those necessitated to fulfill Joint Vision 2010. The other precarious fact is that with the exception of advanced EHF research and development funding, no money has been identified to support any follow-on MILSATCOM architecture in the latest FY98-03 Service Program Objective Memorandum (POMs).

In order to highlight the requirements to capability mismatch, it must be noted that the current architecture cannot support all of today's war plan requirements, let alone those 10 - 15 years into the future where successful prosecution in warfare will be so dependent on the information transfer ability of the forces. Current policy requires the CINCs and Agencies to validate the satellite communications requirements through a body called the Joint MILSATCOM Panel chaired by the Joint Staff with Service representation. For the Major Theater Wars (MTWs) and Lessor Regional Conflicts (LRCs), the CINCs articulate their OPLAN requirements to that panel for approval. Those requirements approved by the panel are maintained in the Integrated Communications Database by DISA. The Joint Staff only allows validated requirements to be satisfied by the system.[8] A similar database for satellite requirements was developed in the past several years to define the requirements for 2010 called the

Emerging Requirements Database (ERDB). After much scrubbing by the CINCs, Services, Agencies and the Joint Staff to insure these requirements were in fact based on real programs the estimated requirements are reflected in Figure 2. If you compare the 15.5 gigabits that must be SATCOM in Figure 2 with the projected capabilities of DSCS, GBS and Milstar combined in Figure 1, the future requirements are estimated at ten times the MILSATCOM wideband capability.

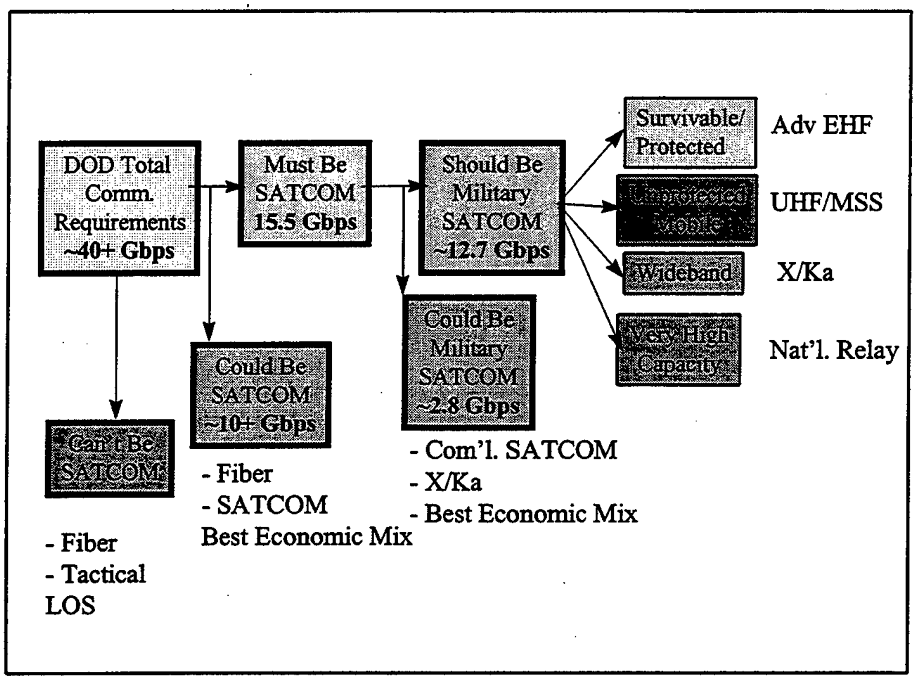

Figure 2. ERDB Requirements Allocation.[9]

Understanding this problem, the Undersecretary of Defense Acquisition and Technology (USD(A&T)) directed his subordinate office, the DOD Space Architect, to develop a follow-on architecture that would satisfy the emerging requirements in the

most cost effective manner. The Space Architect reported out to both the Joint Requirements Oversight Committee (JROC) and the Joint Space Management Board (an interagency group co-chaired by the Deputy Director of Central Intelligence and the USD(A&T) in August 1996 with his recommendations for MILSATCOM.

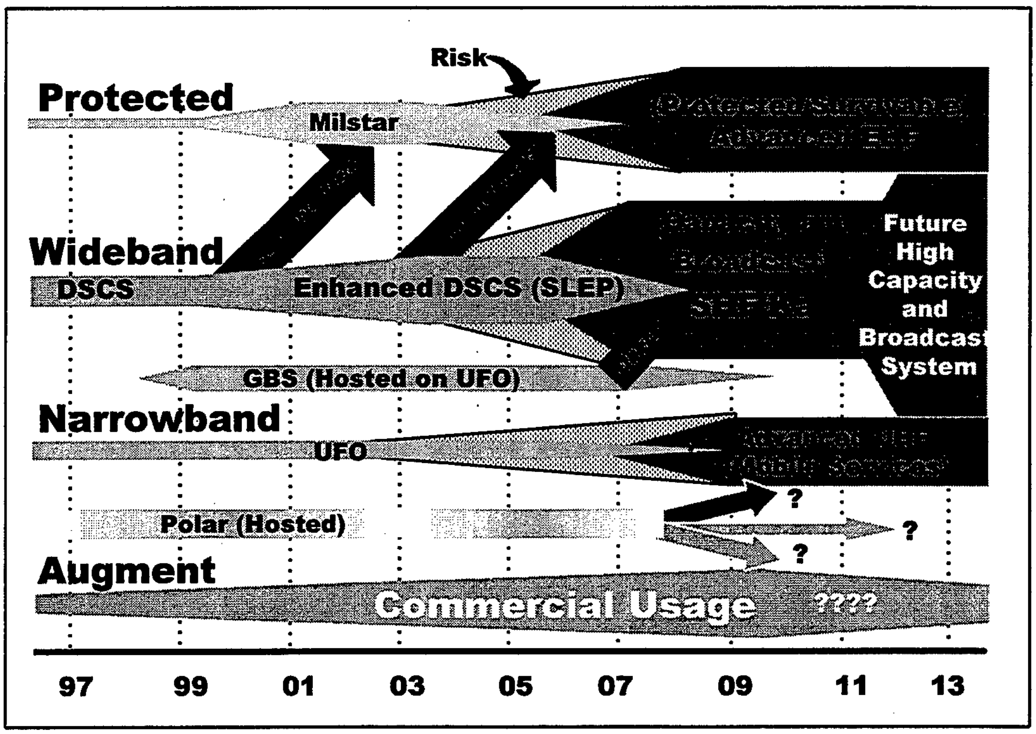

Figure 3. DOD Space Architect Proposed SATCOM Architecture[10]

Specifically he advocated development of a significantly improved advanced EHF capability to satisfy as much of the protected and survivable requirements as possible, to include 24-hour coverage in the north polar region. For wideband capability, he recommended fielding a "commercial-like" transponded system using both the military X and Ka bands for both full duplex high capacity connectivity as well as broadcast

(GBS) capability. He also recommended the investigation of a Civil Reserve Air Fleet (CRAF) like agreements be pursued with industry for both the military and commercial Ka bands. Finally he recommended sustaining UHF capabilities for the time being, evaluating alternatives and deciding by 2005 the means for satisfying these narrowband and netted services in the future.[11]

The JROC provided additional guidance in January 1997 by establishing an affordability goal for future military and leased satellite services spending in the out years to be no more than is reflected in the 1998 President's Budget Submission.[12]

After the JROC direction, DUSD Space and USSPACECOM cosponsored a series of four Senior Warfighter Forums (SWarFs), including flag representation from all CINCs, Services, and Agencies to further analyze the problem, the risks and costs, and develop an affordable solution. They briefed their recommendations as displayed in Figure 4 to the JROC in October 1997 and received their concurrence. The biggest change to the plan was to procure three commercial like wideband gapfiller satellites (X and Ka-band) to start launching in 2004.

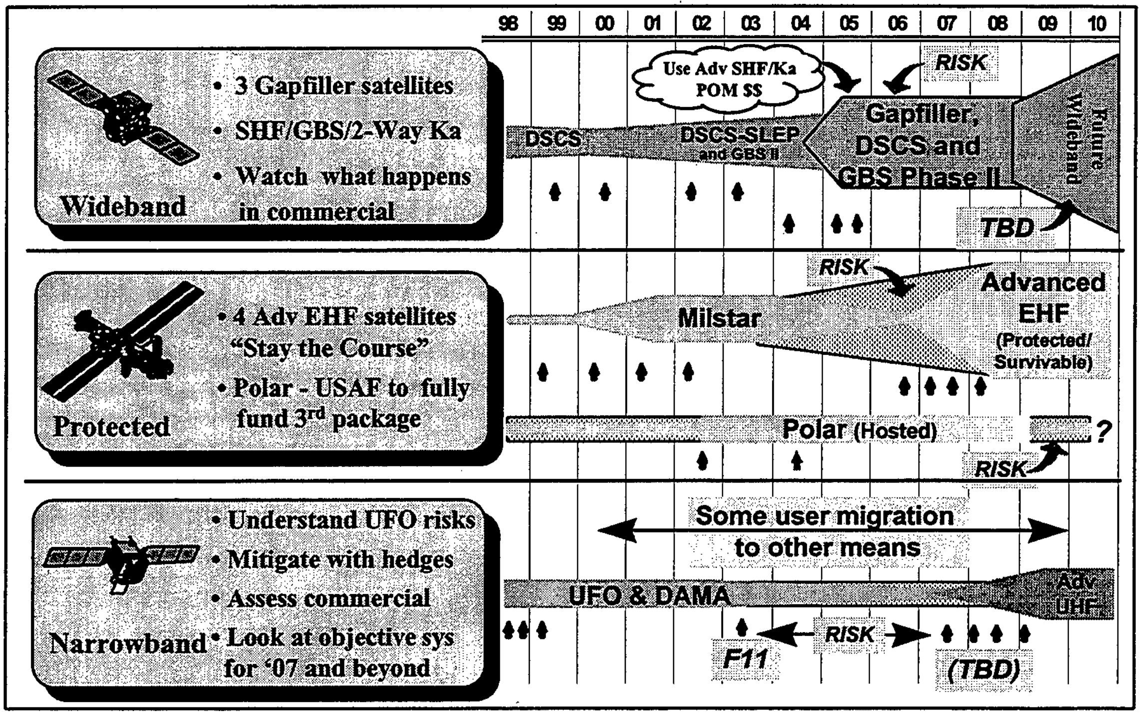

Figure 4. JROC Approved SWarF Course of Action[13]

This will allow for a possible decision to utilize commercial offerings to provide much of the wideband capacity, which today are not mature enough for the warfighter to rely on. Milstar and the Advanced EHF programs must satisfy the protected and survivable requirements, as the commercial market has no need for this unique military capability. The narrowband services provided by the UHF Follow-on (UFO) system will remain as scheduled with a later decision to pursue an advanced military system or exploit commercial satellites.[14]

Military Use of Commercial SATCOM

DOD has used the capabilities of commercial satellite services since the late 1960's to provide telecommunications

services to remote DOD enclaves that could not be served by DOD owned systems and to provide more robust communications to areas in order to avoid complete isolation should there be a DOD satellite failure.[15] The military has used commercial satellite services in military operations from humanitarian operations through high intensity conflict from Rwanda, Haiti, Bosnia through Desert Storm. In Desert Storm the commercial service augmented where there just wasn't any MILSATCOM capacity left but also provided unique capabilities to the military ranging from mobile services provided by Inmarsat, increased Defense Information System Network (DISN) connectivity into the theater as well as commercial telephone service to the soldiers. In the humanitarian and peace keeping operations, it provided the means to reduce the footprint of military communicators in the theater of operations, allowing for a uninterrupted operational transition from US to UN, NATO or host country direction. The Defense Commercial Communications Office (DECCO) is chartered with contracting all commercial communications services for the DOD. They have historically done so on a circuit by circuit, end to end basis. As a normal contracting office secures leases with the lowest bidding service provider, who is generally free to use any means available to provide the desired connectivity. In many

cases the means are via commercial satellites as well. As such the DOD has active commercial leases of satellite bandwidth to the tune of $200 million annually.[16] The two types of service provided today are high bandwidth trunked service between fixed locations, know as fixed satellite services (FSS), as well as mobile satellite services (MSS) generally provided by Intelsat and INMARSAT respectively.

INTELSAT, founded in 1964, is a UN sponsored international not-for-profit cooperative of 142 nations or signatories and is the world's largest commercial satellite communications services supplier providing a global beaming of television, telephone, and data distribution services to users in more than 200 nations distributed on every continent. They operate 20 high powered geostationary satellites in the C and Ku-bands.[17] The largest shareholder is COMSAT, the only U.S. signatory, with almost 18 percent of the consortium.

INMARSAT, established in 1979 to provide mobile communications and safety services, is also an international consortium of over 80 signatories. Their constellation currently consists of four INMARSAT II and four INMARSAT III geostationary satellites providing worldwide coverage, excluding the polar regions. It generally provides direct dial phone services,

facsimile, two way data messaging and electronic mail for over 95,000 registered terminals (cost $3,500) worldwide. Normal services cost $3-6 per minute and the usage has spread to land based users in remote regions as well as emerging airplane service on commercial intercontinental flights.[18] INMARSAT use by the military, especially the Army, began to bloom during Desert Storm and today is extensively used by the Navy as well.[19] The use of INMARSAT is limited to "peaceful purposes" by multinational agreement which has been interpreted by the military for use in humanitarian and peacekeeping support as well as general purpose communications that are not aggressive in nature (administrative, logistics, medical etc.).[20] INMARSAT services are restricted by many nations as well. Limitations range from no use to high annual license fees, taxes and duties that are as high as $10,000 a year and are primarily driven by the concern about bypassing their own terrestrial networks (lost revenue).

The haphazard way DOD was procuring commercial satellite services in general caused much congressional concern in the early 1990's. The Commercial Satellite Communications Initiative (CSCI) program was born out of 1992 Congressional direction to DOD requiring the department to study its long term

communications needs and to determine to what degree and how those needs could be met by projected commercial systems. In response DOD established a policy to augment its military SATCOM capability with domestic and international services to the extent operationally and fiscally practical. These services must meet normal peacetime requirements as well as provide a surge capability to support contingency operations worldwide.[21] The CSCI managed transponder contract was awarded in June 1995 to COMSAT RSI to initiate the service with two transponders with options for up to 45 transponders as paying customers are identified. The CSCI study also envisioned that current government leases would be moved to these transponders as they would be more cost effective and essentially pay for the world-wide coverage.[22] COMSAT would control the power and bandwidth of these channels and unsubscribed capacity could be allocated to tactical requirements on JCS direction. COMSAT would also help facilitate gaining landing rights and host nation approval for terminal equipment located in foreign countries. To date twelve transponders have been leased under CSCI providing coverage as depicted in Figure 5.

CURRENT CSCI TRANSPONDERS

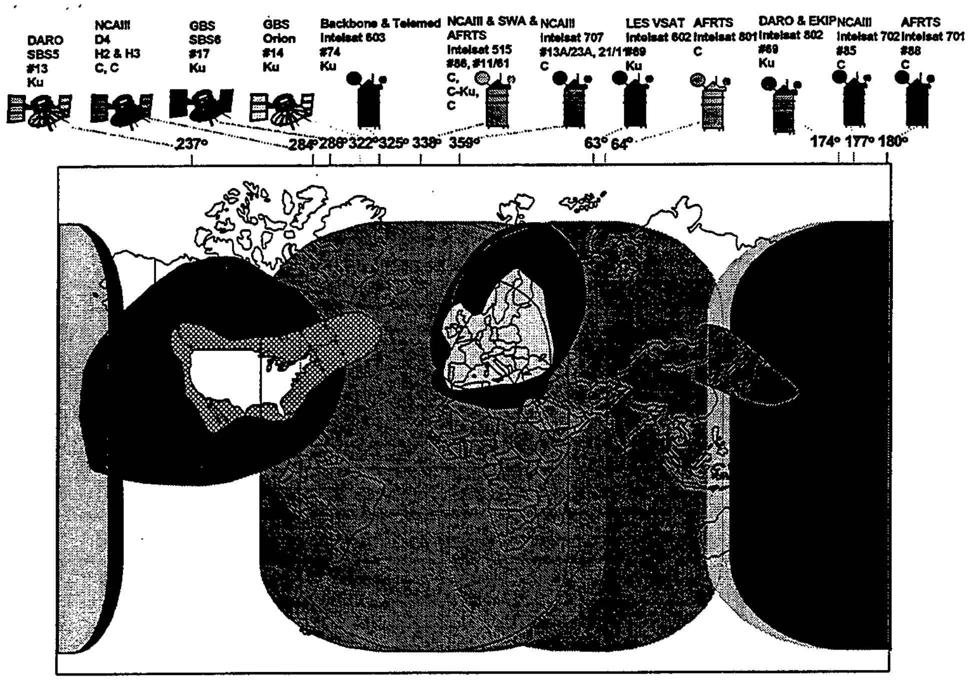

Figure 5. Coverage of CSCI Transponder Leases 1997.[23]

The earth coverage beams primarily serve the Navy in blue water with about 1.5 MBps of data in each ocean. The European spot beams are used for the Joint Broadcast System (JBS) ACTD and intra-theater communications for Bosnia operations. The other spot beams support the Enhanced Korean Improvement Program (EKIP) that provides for more robust connectivity on the peninsula, infrastructure enhancements in Southwest Asia, and a couple used by the Defense Airborne Reconnaissance Office (DARO) for testing of the Dark Star and Global Hawk UAV systems currently under development.

In the process of obtaining commercial services it is necessary to obtain host nation landing rights to terminate the service in a foreign country. The process is simple in the United States but elsewhere can be very frustrating and costly both in time and money. Most governments around the world run their country's telephone service and as with most bureaucracies, can be very inefficient especially if they don't support the operation for political reasons. The host country Intelsat signatory must broker the desired service for the customer. Like the INMARSAT case, they are concerned about lost revenues if the service bypasses their own public systems and satellite terminals and will seek compensation accordingly. In some cases the foreign leg of the system can cost two to three times the US tariff providing for a significant plus up to the gross national product of some third world countries. Figure 6 depicts the average time throughout the world for securing landing rights.

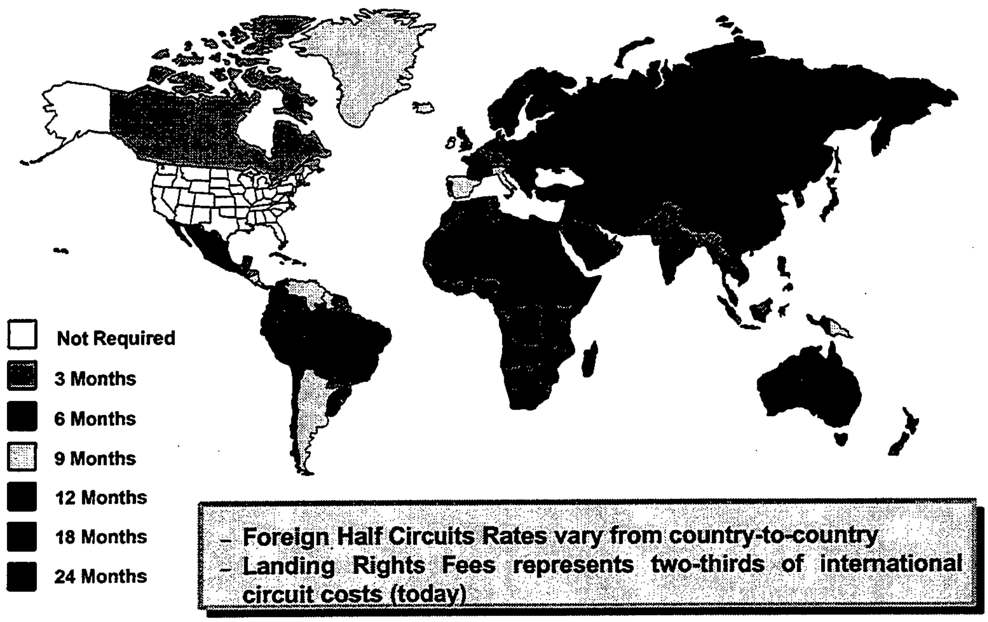

Figure 6. Time Needed To Secure Landing Rights[24]

Two glowing examples that highlight the landing rights problems can be cited in Korea and Saudi Arabia. Although both are our allies and are essentially defended by the US against hostile neighbors, it took over a year, after both the transponder leased and terminal equipment was sited, to get essential commercial satellite service turned on. This problem existed in spite of the fact that both CINCs were personally involved applying pressure on the foreign governments. In the case of South Korea, the issue boiled down to their law requiring commercial terminals be owned and operated by Korean vendors and

was eventually ironed out. The Saudi case was attributable to some political sensitivity associated with the realignment of US forces in the country after the Khobar Towers incident.

On the flip side, the typical host nation problems were overcome in the Bosnia support as they were negotiated at the outset under the Dayton Accords within the confines of the former Yugoslavia before the entry of the U.S. The DISA-COMSAT team has also had some success in negotiating lower tariffs in some countries.

EMERGING COMMERCIAL SATCOM ENDEAVORS

With the exception of INTELSAT, Inmarsat, and a few niche market communications providers the bulk of the space business has been government initiated by the US, the former USSR, France and the United Kingdom. Within the US government, the predominant space players have been the National Air and Space Agency (NASA) for scientific research and exploration, the National Reconnaissance Office (NRO) for overhead intelligence collector systems, and the DOD for missile warning with the Defense Support Program (DSP), navigation aid with the Global Positioning System (GPS) as well as the MILSATCOM systems previously discussed. The government lead in space drove the technology. Since the mid 1990's commercial ventures have become

more prevalent as commercial markets have been developed for imagery of all types to aid in oil exploration, navigation, mapping and farming. The commercial exploitation of the GPS system has been phenomenal, where today you find receivers in cars, trucks, boats and airplanes to aid in their navigation. Spin-off commercial ventures have emerged that integrate GPS data with their corporate transportation systems in order to optimize their traffic for boosted profitability.

Like the GPS system, the growth in commercial satellite communications ventures is beginning to take off as well. In fact based on International Telecommunications Union (ITU) filings for communications satellite systems as reflected in Figure 7, industry will launch over 1100 new communications satellites over the next ten years. These numbers do not reflect replenishment of previously fielded Intelsat Inmarsat systems.

Most communications satellites both military and commercial have been in geosynchronous (GEO) orbits some 22,000 miles above the earth's surface, rotating at the same speed as the earth, fixing the satellite above the equator at a specific longitude. The advantage of this orbit is that near worldwide coverage can be achieved with as few as three satellites. Because GEO satellites appear stationary from the ground, the terminals

Satellite System	Sats	Date	Cost	Prime Partners	Market Service	Band	Orbit
ACeS (Garuda)	2	1999	$900 M	PSN, Philippine LDC, Jasmine Intl	Transponded	Ku	GEO
Africom	1	1999	$650 M	Africom, Lockheed Martin	Transponded		GEO
AMPT	2	1998	$900 M	China et. al.	MSS		GEO
AMSC (Skycell)	2	2000	?	Hughes, Singapore T, AT&T, Baron	MSS		GEO
ASC (Agrani)	2	1998	$1 B	Essar Telecom, Essel Gp.	Transponded		GEO
Astrolink	9	2000	$4 B	Lockheed Martin Telecom	Broadband	Ka	GEO
Celestri	63	2002	$12.9 B	Motorola, Inc	Broadband/Switched	Ka	LEO, GEO
Cyberstar	3	2000	$1.6 B	Loral Space, Alcatel Espace	Broadband	Ka	GEO
E-Sat	6	2000	$50 M	Echostar Ind., DBSIndustries	MSS, messaging		LEO
EAST	1	2000	$700 M	Matra Marconi Space	Transponded		GEO
ECCO (Constellation)	12	1998	$450 M	Telebras, CCI, Bell Atlantic, CTA, E-S	MSS, Low Data		LEO
Ellipso	14 + 3	2000	$910 M	MCH, Vulva C, Orb Sc, Harris, LM et al	MSS		MEO Eliptical
Eutelsat	10	2000		European Consortium	DBS	Ku	GEO
Expressway	14	?	$3.9 B	GM Hughes Electronics	Broadband	V/Ku	GEO
FAISAT	26	2002	$250 M	Final Analysis, Polyot Ent.	MSS		LEO
GE Starsys	24	1998	$170 M	(GE Americon, CLS NA)	MSS, Low Data		LEO
GE Star	9	?	$4 B	GE Americom	Broadband	Ka	GEO
Gemnet	38	1999	$160 M	Orbital Sciences, CTA	MSS, Low Data	L.S	LEO
Globalstar	48	1999	$2.6 B	Loral. Qualcom,France TC, et al	MSS	L,S,C	LEO
ICO	10	2000	$2.6 B	45 telecom co's Inmarsat, Hughes	MSS	C/Ka	MEO, Circ
Inmarsat-3	5	op	$690 M	Inmarsat sigs	MSS		GEO
Iridium	66	1998	$4.4 B	Motorola, Nippon Iridium Co, Sprint et al KaSTAR	MSS		LEO
Leo One	48	2000	$250 M	dBX Corp----	MSS, messaging		LEO
M-Star	72	2002	$1.6 B	Motorola	Broadband	Ka	LEO
M2A	1	1999	$350 M	PSN, Indosat	Telephony		GEO
Millennium	4	2001	$2.3 B	Motorola, Vebacom-- (See Celestri)	Broadband		GEO (part)
Movisat	3	1998	?	Satelites Mexicanos SA	MSS Telephony		GEO
Odyssey	12	2001	$3.2 B	TRW, Teleglobe	MSS	L,S,Ka	MEO
Optus - (MobileSat)	2	op	$75 M	Optus Communications Pty Ltd.	MSS (Australia)		GEO
Orbcomm	28+8	1998	$350 M	Orbital Technologies, Teleglobe, TRI Bhd	MSS, messaging	VHF	LEO
Satphone	3	1999	$1.7 B	Lockheed Martin, Ad Tech F'nd, Amoudi	MSS, Africa		GEO
SkyBridge	64	2002	$3.5 B	Alcatel Espace, Loral Space & Com	Broadband	Ka/Ku	LEO
Spaceway	8	2000	$3.2 B	Hughes Communications	Broadband/DBS	Ka	GEO/MEO
Teledesic	288	2002	$9 B	Bill Gates, Craig McCaw, Boeing Co.	Broadband	Ka	LEO
Thuraya	2	2000	$850 M	Etisalat, Arabsat, Bahrain Telecom	MSS	Ku	GEO
VITAsat	2	1997	$10 M	V'teers in Tech Assist, Final Analysis	Narrowband messag		LEO (Little)

Figure 7. Commercial Communications Satellite Filings [25]

require simplified tracking electronics for one antenna to maintain communications and the complexity of satellite control is minimized. The disadvantages of GEO orbit are the loss of signal strength and the 1/2 second propagation delay caused by the long distances from the orbit to earth. GEO systems also have limited frequency spectrum re-use for multiple users. In the past five years significant advances in satellite power, antenna technology and low noise amplifiers, for both satellite and ground terminals have enabled direct broadcast companies to flourish for worldwide television markets. These same

improvements have been made by Intelsat and Inmarsat to increase their system capacity by an order of magnitude while reducing the terminal costs to their customers.

The other two orbits that industry is pursuing are the Low Earth Orbit (LEO) and Mid Earth Orbit (MEO). The LEO systems orbit somewhere between 500 to 1500 miles above the surface while the MEO is half the GEO distance from the earth. Geometry and orbital mechanics dictate a requirement for many more satellites in the LEO and MEO systems to achieve worldwide coverage. Future MEO systems range from 10 to 17 satellites while future LEO systems will have between 24 to 288 satellites in their respective constellations. The lower orbit systems are significantly more complex because many more satellites need to be controlled and networked. The short dwell times over specific customers require satellite handovers to maintain communications as the satellite passes out of view requiring terminals with very sophisticated antenna tracking electronics and even additional antennas for some high data systems. The advantages lower orbits offer are reduced signal path loss and data propagation delay. These advantages translate into smaller terminal and antenna sizes providing high quality communications services with lower bit error rates and reduced data latency. The ability to reuse

frequency spectrum in lower orbits increases system capacity to more users.

The commercial offerings can be functionally broken down into three categories of services; transponded and broadcast systems, mobile satellite services and switched bandwidth systems. The transponded systems are also known as "bent-pipe" systems since they basically reflect the signal the satellite receives from geosynchronous orbit back to the earth terminals without any processing done on board the satellite. The only discrimination of receive terminals is accomplished by the directed gain provided by the satellite to the receiving terminals and encryption of the signal itself. Aside from the well entrenched Intelsat and Hughes systems today, their are also six new providers of services of this type on the near term horizon. The growth of this market including the expanded capacity achieved in the Intelsat-like systems will be sustained for three good reasons. First today's demand for this service is extremely high given the little excess capacity resident in these systems and the growth of both the trunked data and broadcast television markets. Secondly the terminals currently in use are sunk costs for industry and with well-established and enforced standards and improved technology, the procurement costs for future terminals will continue to drop. Finally, the standards

allow for any terminal of this type to work on any of the transponded systems. The military use of these systems will be dictated by demand as the new tactical ground terminals being deployed over the next five years are tri-band capable (can work in Military X-band as well as the commercial C and Ku bands) and the Navy is outfitting their flag ships with commercial terminals of this type to augment their X-band capability.

Mobile Satellite Services (MSS)

The MSS systems typically provide low rate data (9.6 KBps), messaging, paging and telephone services typically on a worldwide basis. In all cases, the market these companies are pursuing is the personal communications services to areas with little or no communications infrastructure support today. Their indirect competition is the terrestrial based cellular phone services which is provided cheaply in the industrialized western Europe, the U.S. and Japan.

The MSS competition will work in GEO, MEO and LEO (known as "little LEOs") orbits. The GEO providers are seeking niche markets in specific areas (Africa, Mideast, China, Australia, Mexico and the Pacific Rim) and will compete directly with Inmarsat on a regional basis with a few satellites. The LEO systems can be divided into two categories; telephone providers and low rate data and messaging systems. Both system types are

developing hand held "cellular-like" instruments that will use both cellular standard (GSM) as well as their own proprietary protocols. The heavy contenders for the worldwide business are Iridium, Globalstar, Odyssey and ICO Communications (an outgrowth of Inmarsat) but few expect all to survive the competition. The corporate ability to capture the market share first with reliable and affordable capability will characterize the winners of the stiff competition. Besides current military use of Inmarsat, the military plans to use the Iridium system and has programmed over $100M to purchase a DOD gateway in Hawaii in order to enable STU-III security as well as provide some level of protection of user location information.

Switched Bandwidth Systems

The high bandwidth switched systems like the MSS systems see a market for high bandwidth worldwide customers who lack robust communications infrastructure, obviating the need for developing economies to build such an infrastructure. At the same time, these enterprises look to bypass the fixed infrastructure telephone, cable, and long haul fiber optic providers in developed nations by providing cheaper and more flexible alternatives to customers. These systems rely on either GEO or LEO (known as big LEOs) constellations or hybrids using both. In order to compete with the high quality fiber communications systems, most of the companies look to the LEO systems to reduce the inherent data latency problem and provide "fiber-like" quality data communications. In all cases, cross-linking between satellites enables direct communications almost anywhere on the globe. Both Hughes' Spaceway System and Lockheed-Martin's Astrolink rely strictly on GEO satellites to provide service. Other broadband GEO filings like Loral's CyberStar and Motorola's M-Star have been combined with LEO systems in hybrid constellations. Loral has teamed with the French firm Alcatel to merge their Skybridge LEO system and Motorola has combined their own Millennium GEO system and M-Star LEO system into a hybrid called Celestri. All these high bandwidth systems use commercial

Ka-band to communicate with ground terminals. The constellation capacity of these systems varies from ten to a hundred gigabits per second or more (Celestri and Teledesic). Figure 8 captures the major commercial vendors projected initial capability dates for the emerging MSS and Ka Switched bandwidth enterprises.

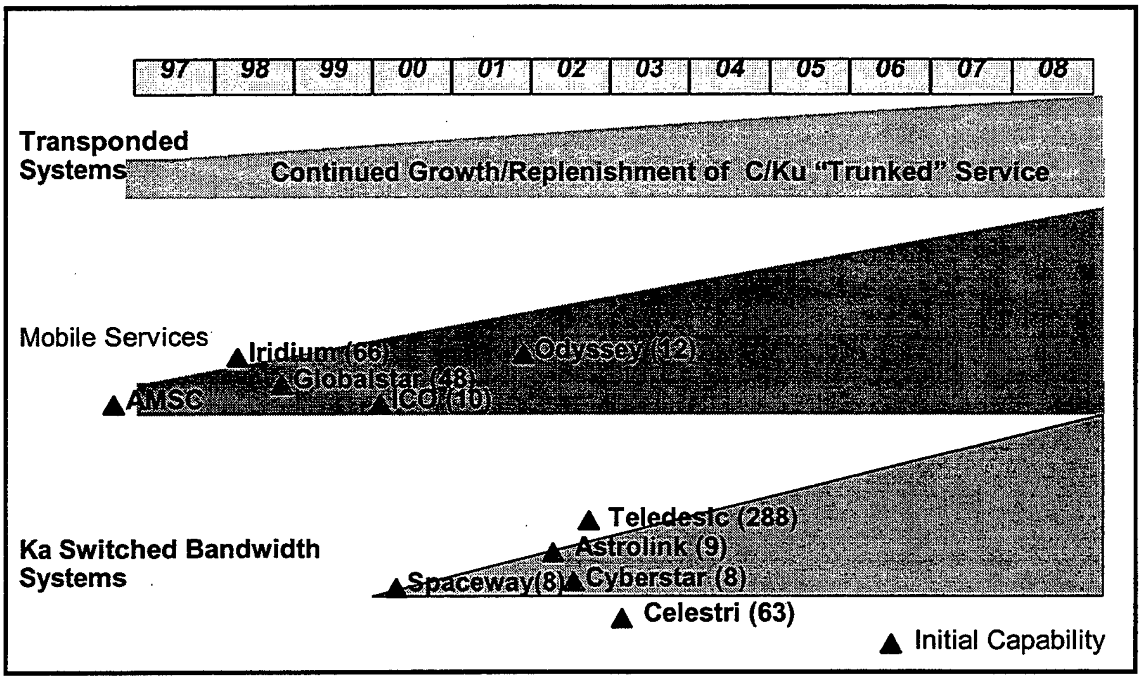

Figure 8. Market Growth Trends [26]

COMMERCIAL VERSUS MILITARY SATCOM - TRADEOFFS

If there were any guarantees that emerging commercial systems could meet the required MILSATCOM capabilities of instant accessibility, survivability, coverage, flexibility and global reach, and do it more affordably, than there would be no doubt that we should transition to commercial systems. But that is certainly not the case in general as nothing is guaranteed in

these commercial ventures. So some discussion of comparative costs, risks and capabilities versus the requirements needs further discussion to determine where it is technically feasible and more affordable to depend on commercial SATCOM to meet the requirements.

First of all, industry has no commercial market for developing systems able to work through a stressed environment from nuclear events, jamming to low probability of intercept (LPI) and detection (LPD). However, the complexity and focused coverage of the LEO systems make jamming these systems more difficult and effects of such efforts more localized. This same complexity seems to help satisfy LPI and LPD requirements but the locations and identification of users passes through each commercial system for billing purposes and can hardly be considered reliable for covert communications. As such the military cannot depend on industry to satisfy these requirements. The narrow-band and wide-band capability of the UFO and DSCS systems respectively can technically be met by industry offerings to a large degree, and further discussion of commercial possibilities in these areas is warranted.

Today, the commercial market (less Inmarsat and ICO) is generally focused on land masses and population centers as that is where the customers are. As such, the vendors must optimize

their systems to them for profitability reasons. The military typically does not deploy to these regions, so adequate support for tactical operations can not be guaranteed. Even if DOD were completely reliant on industry, the government market share would be at best 10% of a system, hardly enough to redirect resources without severe cost to the vendors. However 75% of the MILSATCOM wideband requirements are not for tactical communications. They are fixed "infrastructure-like" requirements for DISN, strategic intelligence and State Department traffic, as well as government satellite control. These types of fixed requirements are a better meld with the commercial markets.

The military netted radio capability provided by the current UHF constellation is not inherent in any of the commercial MSS designs today. Because the netted SATCOM is so integrated in the command and control of Joint and Service operations, the DOD will not become completely dependent on the commercial MSS systems until the vendors adapt to provide such a capability. Industry is not likely to adapt, unless a simple, low-cost technical solution can be achieved to provide netted services.

There are many people in both government and industry that believe that commercial communication is cheaper than government owned. There are few examples where this is true for small requirements to remote areas but is generally **<u>not</u>** the case today.

Detailed independent studies have estimated lease costs from CSCI transponders required to satisfy DOD requirements range from twice as costly[27], five times as costly,[28] to as much as 14 times as costly in a most recent GAO study. In fact, the GAO recommended acceleration of a "commercial-like" DOD owned wideband system in order to save almost $3 Billion in leasing costs between now and 2006.[29] Obviously, leasing is not the road DOD should be on at all.

Different arrangements should be pursued as possible alternatives to leasing. Given that these emerging systems have yet to be launched or captured the market, different partnering arrangements with industry such "anchor investor" and "anchor tenant" are possible and should be considered. The anchor investor partnership is made very early in the business design phase while the tenant relationship is reached after design and before system initial operational capability is reached. Assuming a certain amount of capacity desired, the anchor investor would get it cheaper than the anchor tenant and would be likely to influence the design to favor the government requirements. Figure 9 highlights the availability and investment risks the government assumes in different working relationships with industry. The earlier the partnership is

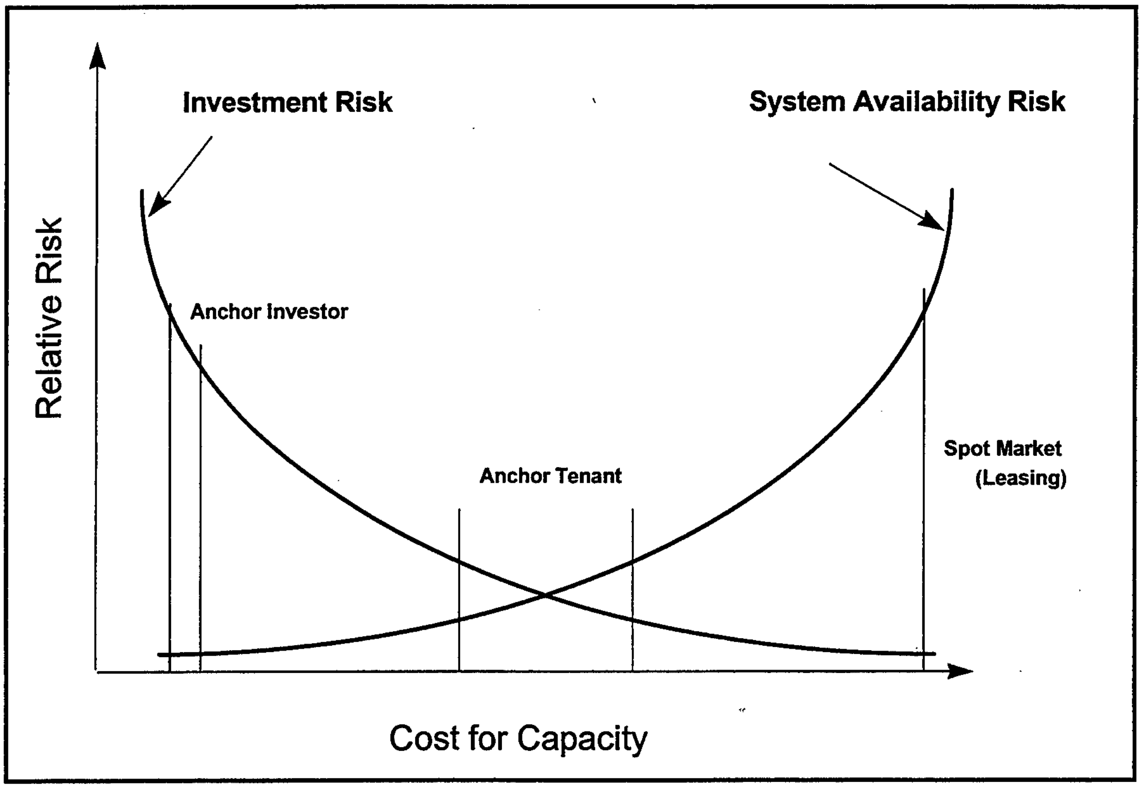

Figure 9. Risks Assumed With Government Use of Commercial.[30]

formed the cheaper the cost per bit, but the higher the risk that the company may not survive the competition ("buying Betamax"). The risks are minimized as the market matures and the clear winners become evident.

Another primary consideration is who owns the company. Few of these ventures can be considered American owned and operated. In cases where it appears to be true, large capital investments from foreign industry is commonly present. As such, analysis must be performed to determine how susceptible each would be to deny, exploit and disrupt services should government or non-

government actors not support our military operations. Any partnering arrangements should require the firm to mitigate these concerns with design and procedural changes. From an economic warfare sense, consideration should be given to how much revenue the Government pays for service, actually benefits US companies and citizens. Ideally, we would want to partner with a US owned and operated company to minimize these concerns.

CONCLUSIONS - THE WAY AHEAD

The future US military capability will be dependent on SATCOM to provide the connectivity for the increasingly lethal mobile, dispersed Joint forces envisioned in 2010. The recent decision of the SWarF and JROC indicate that for the near term, the role of commercial satellite providers will be to augment MILSATCOM where the military systems can not meet the ever increasing requirements. The explosion of commercial ventures in space communications may allow for more reliance on them to satisfy the military needs. The question for DOD is to sort out how dependent we should be. The military can not depend on industry to provide survivable communications for control of nuclear forces as there is no commercial market for it and the additional costs associated with hardening such systems would not make good business sense. There are potential opportunities in

using and adapting MSS, transponded and high bandwidth switched systems to meet the explosion of MILSATCOM requirements.

There is real potential today for the military to exploit the commercially driven SATCOM technology capability vice the normal military acquisition process. There is potential to replace some of the MILSATCOM architecture, as well as the control and management overhead associated with it, with commercial capability. The highest potential exists in pursuing partnership arrangements with industry. Partnerships would yield a better return of investment than buying on the spot-market. As the cost for partnering arrangements will go up with time, it is essential for DOD to earnestly explore the possibilities. The market volatility as these ventures rush their systems to the market brings high risk (technical and business) for early partnering decisions. This allows DOD only a couple of years for dialog with industry, to analyze the possibilities and pursue the most cost-effective course of action.

We will surely migrate away from military specified satellite communications systems for the majority of the requirements for both cost and interoperability reasons. Cooperation with industry and allied governments will be required to achieve the most cost-effective interoperable solutions. Whether commercial satellite companies or government owned

"commercial-like" systems operating in military frequencies will provide the communications beyond 2010 will be decided after careful review of the cost and capability tradeoffs.

(Word Count 6,540)

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